# PATENT SPECIFICATION

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## (54) METHOD OF PRODUCING HIGH-STRENGTH COLD-FORMED PARTS

(71) We, VEB SCHRAUBEN-KOMBINAT, of 34—36, Reichenhainer Strasse, 901 Karl-Marx-Stadt, German Democratic Republic, a Corporation organised under the laws of the German Democratic Republic, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to a method of producing high-strength cold-formed parts, for example screw bolts and nuts, of unalloyed and low-alloy cold working steels.

There are various previously known methods of producing cold-formed parts having a high strength viz. a tensile strength of $\delta_{ZB} \geqq 750$ N/mm² and a yield point of $\delta_s \geqq 600$ N/mm². In one known method unalloyed or low-alloy cold working steels are first formed, followed by hardening and tempering. In another method, unalloyed and low-alloy cold working steels which have already been given the necessary strength properties by previous heat treatment (hardening and tempering, carburisation) are subsequently formed. Certain extrusion methods or a succession of forming operations with the same forming direction, for example stepwise cold forming of rods or bars of commercial low strength steels to form profiled reinforcement steel have also been proposed.

These known production methods have disadvantages in the sense that the hardening and tempering process does not permit a continuous production cycle; that heat treatment preceding cold-forming requires extensive plants and entails increased power consumption in the subsequent upsetting; that extrusion methods entail greater expenditure for tools in respect of their number and shape, as well as special machines; and that stepwise cold-forming in the same forming direction cannot be applied to the production of high-strength screw bolts, nuts and similar cold-formed parts.

The invention aims at obtaining a more economical production of high-strength cold-formed parts, particularly screw bolts and nuts, by reducing costs of labour, power and materials, providing more favourable pre-requisites for their automatic production, and achieving greater uniformity of strength properties.

The problem underlying the invention is that of providing a method of producing high-strength cold-formed parts of unalloyed or low-alloy cold working steels by work hardening resulting from a modification of the cross-section of commercial bar or wire steel used, followed by effective cold working.

To this end, the present invention consists in a method of producing high strength cold-formed parts having a tensile strength $\delta_{ZB} \geqq 750$ N/mm² and a yield point $\delta_s \geqq 600$ N/mm² from unalloyed or low-alloy bar or wire steel with a carbon content below 0.6% and a tensile strength $\geqq 500$ N/mm² in the soft annealed or as rolled condition, which comprises increasing the strength of the steel by cold working in the form of drawing, to reduce the cross-section of the bar or wire between 20 and 60% in dependence on the required strength properties of the finished cold-formed part in accordance with the flow curve of the steel used and taking into consideration the required diameter of the finished cold-formed part, and thereafter subjecting the bar or wire to further cold working in the form of compressive upsetting in the opposite direction to that of drawing.

In order that the invention may be more readily understood, reference is made to the drawings accompanying the Provisional Specification which illustrate diagrammatically and by way of example the method of the invention and in which:—

Figure 1 is a graph illustrating the tensile strength plotted against the reduction in cross-sectional area (as a logarithm;) and

Figure 2 is a graph illustrating the upsetting stress plotted against the reduction in cross-sectional area.

The various steels used in the graphs have the following composition in %:—

| | C | Si | Mn | P/S | Cr |
|---|---|---|---|---|---|
| 37.MnSi5 | 0.31—0.39 | 1.10—1.40 | 1.10—1.40 | 0.035 | — |
| 35 Cr2 | 0.35—0.40 | 0.17—0.37 | 0.50—0.80 | 0.04 | 0.40—0.70 |
| CQ35 | 0.35—0.40 | 0.17—0.37 | 0.50—0.80 | 0.04 | — |
| MU8 | 0.06—0.10 | — | 0.25—0.40 | 0.04 | — |

A hexagonal bolt of 8 mm diameter and 45 mm length is produced from CQ 35 steel, for example, in the following process stages:

A cold working steel rod, with a carbon content below 0.6%, and having a diameter of 10.5 mm, is soft annealed ($\delta_{ZB}=500\ldots 560$ N/mm$^2$ and thereafter pickled and phosphated.

Tensile strength of the wire is increased to $\delta_{ZB}>800$ N/mm$^2$ by cold working in the form of drawing the wire to a reduced diameter of 7.09 mm which represents a decrease in cross-section of about 54.3%.

The bolt blanks are completed by cold working the wire in the opposite direction to drawing by compressive upsetting in a multi-stage cold header followed by thread rolling.

The above mentioned cross-section reduction associated with the strength increase is to be kept within such limits that, for one thing, a deformation is still possible at all and, for another, the necessary starting diameter, for example for achieving the nominal diameter of thread in the case of screws is still present during the subsequent thread production.

The prerequisite for a further good cold-working capacity after the stress hardening, taking into account the appropriate grade of steel, consists in adhering to the following three conditions which mutually influence one another in the stress hardening process:

obtaining the required strength of the cold-formed part (Fig. 1), and

keeping to a specific cross-section decrease between 20% and 60% (Fig. 2).

In the graphic representations (Fig. 1, Fig. 2), the influencing factors are shown.

Thus, the cross-section decrease of $\varepsilon_A=54.3\%$ for a CQ 35 steel gives a compression upsetting stress $\delta_{d2}=99$ kp/mm$^2$ (Fig. 2) and corresponds to a strength of 85.5 kp/mm$^3$ (Fig. 1).

Since, depending on its grade, the cold working steel is available for further processing in either the soft annealed or as rolled condition, the necessary increase in strength in accordance with the example is achieved through the work hardening of the wire or bar material by drawing. The reduction in cross-section necessary for this purpose is proportional to the strength required obtained from the flow curve of Figure 1, taking into consideration the required diameter of the finished cold-formed part, which diameter in the foregoing example the part must still have in order to achieve the nominal screwthread diameter in the subsequent formation of the screwthread. Through the subsequent application of further cold-forming in the form of compressive upsetting in the opposite forming direction to that of drawing, particularly favourable conditions in respect of power requirements are achieved. The compressive force required in this case for the forming of a work-hardened steel is less than or equal to that required when using a steel which has not been work hardened, provided that conditions corresponding to Figure 2 are maintained, i.e. range of cross-section reduction drawing being between 20 and 60%.

The technical-economic advantage of the invention consists in that the necessary strength of, for example screw bolts, nuts and the like, can be achieved without the technologically laborious and expensive heat treatment, while economic cold formability of the work hardening steel is ensured.

WHAT WE CLAIM IS:—

1. A method of producing high strength cold-formed parts, having a tensile strength $\delta_{ZB}\geqq 750$ N/mm$^2$ and a yield point $\delta_s\geqq 600$ N/mm$^2$ from unalloyed or low-alloy bar or wire steel with a carbon content below 0.6% and a tensile strength $\geqq 500$ N/mm$^2$ in the soft annealed or as rolled condition, which comprises increasing the strength of the steel by cold working in the form of drawing, to reduce the cross-section of the bar or wire between 20 and 60% in dependence on the required strength properties of the finished cold-formed part in accordance with the flow curve of the steel used and taking into consideration the required diameter of the finished cold-formed part, and thereafter subjecting the bar or wire to further cold working in the form of compressive upsetting in the opposite direction to that of drawing.

2. A method of producing high strength cold-formed steel parts, substantially as here-

inbefore described with reference to and as shown in the drawings accompanying the Provisional Specification.

3. Cold-formed steel parts whenever produced by the method claimed in either of the preceding claims.

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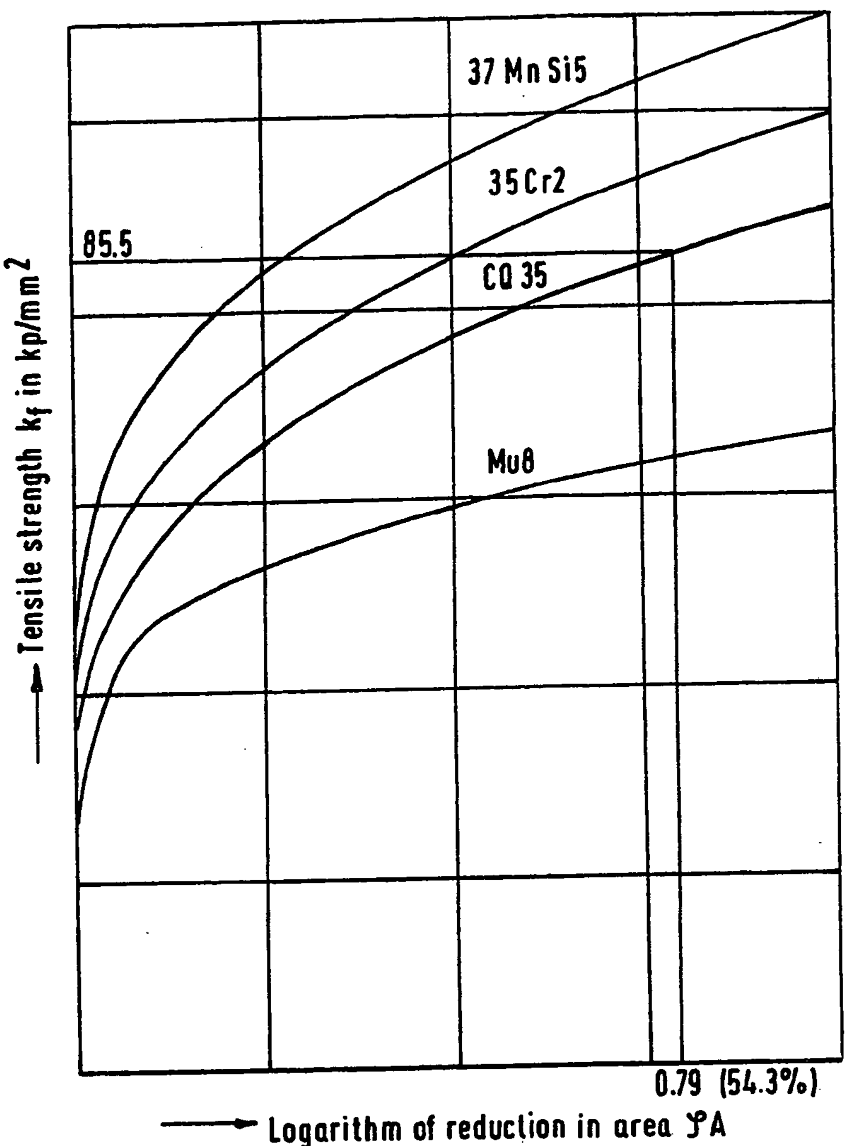
37 Mn Si5
35 Cr2
85.5
CQ 35
Mu8
Tensile strength $k_f$ in $kp/mm^2$
0.79 (54.3%)
Logarithm of reduction in area $\varphi A$

FIG.1

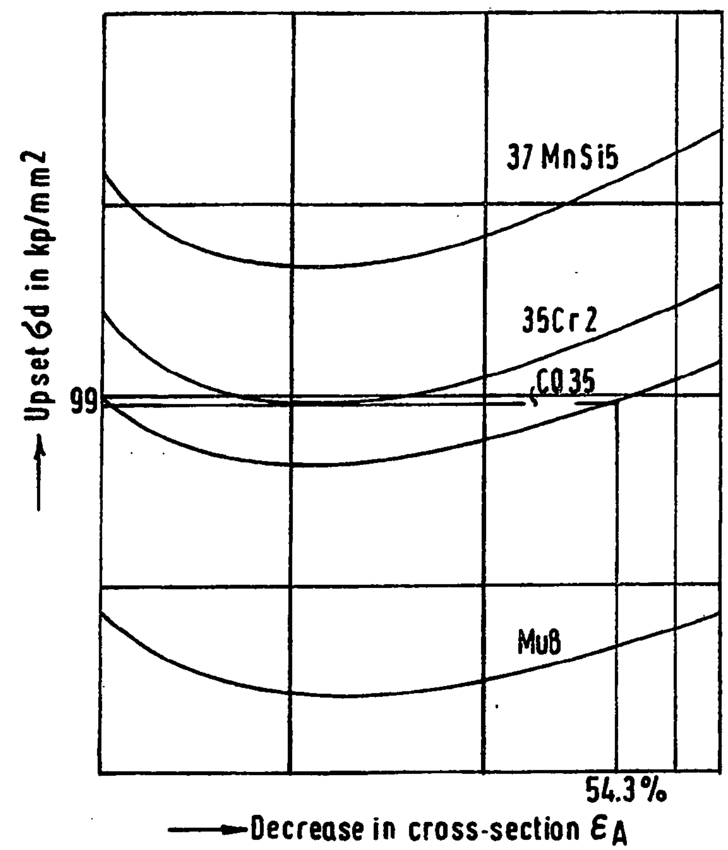
37 MnSi5
35Cr2
CQ35
MuB
99
54.3%
Upset σd in kp/mm2
Decrease in cross-section εA

FIG.2